3

Radionavigation System Use

This section summarizes the plans of the Federal Government to provide general-purpose and special-purpose radio aids to navigation for use by the civil and military sectors. It focuses on three aspects of planning: (1) the efforts needed to maintain existing systems in a satisfactory operational configuration; (2) the development needed to improve existing system performance or to meet unsatisfied user requirements in the near term; and (3) the evaluation of existing and proposed radionavigation systems to meet future user requirements. Thus, the plan provides the framework for operation, development, and evolution of systems.

The Government operates radionavigation systems which meet most of the current and projected civil user requirements for safety of navigation, promotion of reasonable economic efficiency, and positioning and timing applications. These systems are adequate for the general navigation of military craft as well, but none completely satisfies all the needs of military missions or provides highly accurate, three-dimensional, worldwide navigation capability. GPS satisfies many of these general and special military requirements. GPS has broad potential for satisfying current civil user needs or for responding to new requirements that present systems do not satisfy. It could ultimately become the primary worldwide system for military and civil navigation and position location.

3.1 Existing Systems Used in the Phases of Navigation

It is generally accepted that the needs for navigation services derive from the activities in which the users are engaged, the locations in which these activities occur, the relation to other craft and physical hazards and, to some extent, the type of craft. Because these differences exist, navigation services are divided by classes or types of users and the phases of navigation. These divisions are summarized in Tables 3-1 through 3-3. These tables also show current application of the existing radionavigation systems in the various phases of navigation. Detailed descriptions of the existing and proposed radionavigation systems are given in Appendix A.

The systems listed in Table 3-1 are used singly or in combination to support functions of the various phases of civil navigation. Tables 3-2 and 3-3 compare common-use systems to mission applications for military use. Table 3-4 provides estimates of the current numbers of users of Federally provided radionavigation systems. The following sections describe the approach employed to define the needs, requirements, and degree to which existing systems satisfy user needs.

3.1.1 Air Navigation

VOR/DME forms the basis of a safe, adequate, and trusted international air navigational system, and there is a large investment in ground equipment and avionics by both the Government and users. In view of this, it is intended to maintain the VOR/DME system at its present capability for a reasonable transition period after augmented GPS is approved as a primary navigation system. The current ICAO protection date extends to January 1, 1998.

As evidenced by user conferences and aircraft equipage, there is increasing interest and usage of GPS and Loran-C for air navigation. Both systems are certified as supplemental systems. In 1994, unaugmented GPS was also approved as a primary system for use in oceanic and remote airspaces. The GPS WAAS, which is scheduled to be implemented in 1997, is expected to be certified as a primary navigation system. This will allow termination of many existing ground-based radionavigation aids after an adequate transition period to allow users to equip with WAAS avionics.

Oceanic En Route: Oceanic en route air navigation is currently accomplished using inertial reference system/flight management computers, inertial navigation systems (INS), Omega, Loran-C, GPS, or a combination of these systems. Use of Doppler and celestial navigation is still approved. Use of VOR/DME, TACAN, and Loran-C is approved where there is adequate coverage.

Domestic En Route: Domestic en route air navigation requirements are presently being met, except in some remote and offshore areas. The basic short-distance aid to navigation in the U.S. is VOR alone, or collocated with either DME or TACAN to form a VOR/DME or a VORTAC facility. This system is used for en route and terminal navigation for flights conducted under Instrument Flight Rules. It is also used by pilots operating under Visual Flight Rules. The U.S. and all other member states of ICAO have agreed to provide VOR/DME service to international air carriers up to January 1, 1998. Loran-C, Omega, and inertial systems are also used for domestic en route navigation. When inertial systems are used, their performance must be monitored through the use of an approved externally referenced radio aid to navigation. Loran-C and GPS both are approved as supplemental systems. GPS is

Table 3-1. Civil Radionavigation System Applications

MODE	SYSTEMS							
	LORAN-C	OMEGA	VOR/DME	MLS/ILS	TRANSIT	RADIO-BEACONS	GPS	AUG-MENTED GPS
AIR								
EN ROUTE/TERMINAL								
Remote Areas	X	X	E	-	-	X	X	X
Special Helicopter	X	E	E	-	-	X	X	X
Oceanic En Route	X	X	-	-	-	-	X	X
Domestic En Route	X	X	X	-	-	X	X	X
Terminal	X	-	X	-	-	X	X	X
AIRPORT SURFACE	-	-	-	-	-	-	-	E
APPROACH/LANDING								
Nonprecision	X	X	X	-	-	X	X	X
Precision	-	-	-	X	-	-	-	X
MARINE								
Ocean	X	X	-	-	X	X	X	-
Coastal	X	-	-	-	-	X*	X	X
Harbor &				-				
Harbor Approach	-	-	-	-	-	X*	-	X
Inland Waterways	-	-	-	-	-	-	-	X
LAND								
Navigation	X	X	-	X	X	X	X	X
SPACE								
Navigation/Tracking	-	-	-	-	-	X	X	X
Terminal Approach	-	-	-	-	-	-	X	X
Terminal Landing	-	-	-	X	-	-	X	X
OTHER								
AVM/AVL	X	X	-	-	-	-	X	X
Site Registration	-	-	-	-	-	-	X	X
Surveying	-	-	-	-	-	-	X	X
Timing/Frequency	X	X	-	-	-	-	X	X
Meteorology	X	X	-	-	-	-	X	X

LEGEND

X Current or Planned Application
E System in Evaluation
- System Not Used
** Includes Racons*

Table 3-2. DOD Radionavigation System Applications

USAF AND ARMY AVIATION MISSIONS	SYSTEM								
	LORAN-C	OMEGA	VOR/DME	TACAN	MLS/ILS	TRANSIT	RADIO-BEACONS	GPS	AUG-MENTED GPS
EN ROUTE									
Foreign									
Domestic	-	-	X	X	-	-	X	X	-
Domestic	-	-	X	X	-	-	X	X	-
Combat Theatre	-	-	-	X	-	-	X	X	-
Overwater	X	X	-	-	-	-	-	X	-
Remote Area	X	X	-	-	-	-	X	X	-
TERMINAL	-	-	X	X	-	-	X	X	-
APPROACH/ LANDING									
Nonprecision	-	-	X	X	-	-	X	X	E
Precision									
Landing	-	-	-	-	X	-	-	X	E
SPACE									
Launch/Abort	-	-	-	X	X	-	-	X	-
Orbital	-	-	-	-	-	-	-	X	-
Re-Entry	-	-	-	-	-	-	-	X	-
SURVEYING	-	-	-	-	-	-	-	X	-
TARGET ACQUISITION	-	-	-	X	-	-	X	X	-
AERIAL RENDEZVOUS	-	-	-	X	-	-	X	X	-

LEGEND

X Current or Planned Application
E System in Evaluation
- System Not Used
** Includes Racons*

Table 3-2. DOD Radionavigation System Applications (Cont.)

NAVAL MISSIONS	SYSTEM								
	LORAN-C	OMEGA	VOR/DME	TACAN	MLS/ILS	TRANSIT	RADIO-BEACONS	GPS	AUG-MENTED GPS
EN ROUTE, GENERAL PURPOSE									
Ship	X	X	-	-	-	-	X	X	-
Submarine	X	X	-	-	-	-	-	X	-
Air	-	-	-	-	-	-	X	X	-
SEARCH & RESCUE									
Ship	-	-	-	X	-	-	-	X	-
Air	-	-	-	-	-	-	-	X	-
MINE COUNTER-MEASURES									
Ship	X	X	-	-	-	-	-	X	-
Air	-	-	-	X	-	-	-	X	-
MINE LAYING									
Ship	X	-	-	-	-	-	-	X	-
Submarine	-	X	-	-	-	-	-	X	-
Air	-	X	-	X	-	-	-	X	-
AMPHIBIOUS WARFARE									
Ship	-	X	-	-	-	-	X	X	-
Air	-	-	-	X	-	-	-	X	-
ANTI-AIR WARFARE									
Ship	X	X	-	-	-	-	-	X	-
Air	-	-	-	X	-	-	-	X	-
SURFACE WARFARE									
Ship	X	X	-	-	-	-	-	X	-
Submarine	X	X	-	-	-	-	-	X	-
Air	-	X	-	X	-	-	-	X	-
ANTI-SUBMARINE WARFARE									
Ship	-	X	-	-	-	-	-	X	-
Submarine	-	X	-	-	-	-	-	X	-
Air	X	X	X	X	X	-	X	X	-
LOGISTICS									
Surface	X	X	-	-	-	-	-	X	-
Submarine	X	X	-	-	-	-	-	X	-
Air	X	X	X	X	X	-	X	X	-
SURVEYING									
Surface	X	X	-	-	-	-	-	X	-
Submarine	X	X	-	-	-	-	-	X	-
Air	X	X	X	X	-	-	X	X	-

LEGEND

X Current or Planned Application
E System in Evaluation
- System Not Used
** Includes Racons*

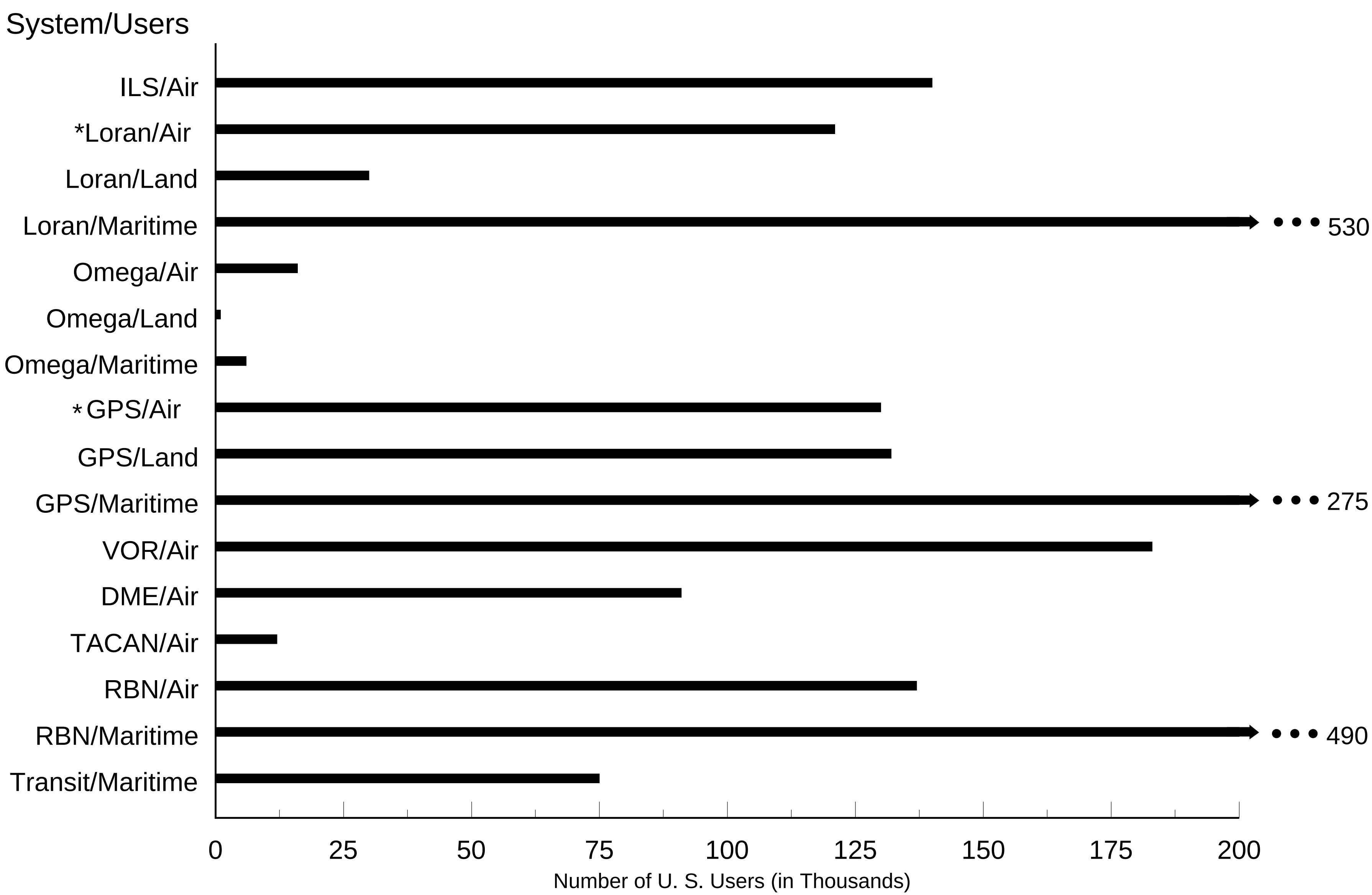
Table 3-3. Defense Mapping Agency Radionavigation System Applications

Applications	SYSTEMS				
	LORAN-C	OMEGA	TRANSIT	GPS	AGPS
WORLDWIDE POSITIONING OF SATELLITE (ORBITAL TRACKING)					
Low Altitude	-	-	-	X	-
Medium Altitude	-	-	-	X	-
High Altitude	-	-	-	X	-
GEODETIC POSITIONING BY SATELLITE (RELATIVE)	-	-	-	X	-
GEODETIC POSITIONING (CONVENTIONAL)	-	-	-	X	-

LEGEND

X Current or Planned Application
- System Not Used

Table 3-4. Estimated Current Radionavigation System User Population



*Includes a large number of receivers that are not certified for IFR use, including handheld receivers also approved as a primary system for use in remote areas, and can be used to provide separation between aircraft in accordance with current DME standards.

Terminal: Terminal air navigation requirements are presently met using VOR, VOR/DME, VORTAC, TACAN, NDB, GPS, or Loran-C. Loran-C and GPS are approved as supplemental systems.

Approach and Landing: Nonprecision approach navigation requirements are presently met using ILS localizer, VOR, VOR/DME, VORTAC, TACAN, GPS, Loran-C, or NDB. Loran-C and GPS are approved as supplemental systems. Precision approach and landing requirements are presently met by ILS (Categories I,II, and III) and MLS (a limited number of Category I systems only).

3.1.2 Marine Navigation

Marine navigation comprises four major phases: inland waterway, harbor/harbor approach, coastal, and oceanic. The phase of navigation in which a mariner operates determines which radionavigation system or systems will be the most useful. While some radionavigation systems can be used in more than one phase of marine navigation, the most promising system to meet the most stringent requirements of the harbor/harbor approach and inland waterway phases of marine navigation is differential GPS. With regard to the coastal phase of navigation, DGPS will provide the navigational features currently being met by Loran-C as it is used in the repeatable mode of navigation.

Inland Waterway Phase: This phase of navigation is concerned primarily with those vessels which are not oceangoing. Specific quantitative requirements for navigation on rivers and other inland waterways have not yet been developed. Visual and audio aids to navigation, radar, and intership communications are presently used to enable safe navigation in those areas. However, the potential for differential GPS to play an increasing role in this phase of navigation is possible. Loran-C coverage of the 48 conterminous states provides some capability, but without integrating the use of Loran-C into another system such as DGPS, it alone does not meet the requirements of inland waterways navigation.

Harbor/Harbor Approach Phase*:* Navigation in the harbor/harbor approach areas is accomplished through use of fixed and floating visual aids to navigation, radar, and audible warning signals. The growing desire to reduce the incidence of accidents and to expedite movement of traffic during periods of restricted visibility and ice cover has resulted in the implementation of VTS and investigation of the use of radio aids to navigation. The differential GPS system is anticipated to meet the navigational needs for this phase of navigation, but it will be necessary to integrate it with an electronic chart display information system (ECDIS).

The USCG plans to install DGPS for harbor/harbor approach navigation. The coverage will include all coasts of the continental U.S. and parts of Alaska, Hawaii, and the Great Lakes. The system will be complete by the end of 1996 and will provide between 2 and 20 meter accuracy.

Coastal Phase*:* Requirements for operation within the coastal area are now fully met by Loran-C, which was fully implemented by 1980, as well as by the Navy’s Transit system. GPS now also meets these needs.

Radiodirection Finders (RDF), required in some merchant ships by international agreement for search and rescue purposes, are also used with the radiobeacon system for navigation.

Ocean Phase: Navigation on the high seas is accomplished by the use of dead-reckoning, celestial fixes, self-contained navigation systems (e.g., inertial systems), Loran-C, Omega, Transit, and GPS. GPS reached its Initial Operational Capability (IOC) on December 3, 1993, and is now the system of choice for this phase of marine navigation. Worldwide coverage by most ground-based systems such as Loran-C is not practicable. The Omega system, however, with all eight stations operational, does provide essentially worldwide coverage.

3.1.3 Land Navigation

GPS and Loran-C are used in land vehicle navigation, although the Government does not have a specific responsibility under law to provide radionavigation systems for civil land use. However, under the general provisions for improving the safety and efficiency of transportation, a number of projects have been sponsored by government and industry to evaluate the feasibility of using existing and proposed radionavigation systems for land navigation. Many land navigation applications are being developed, while others are beyond the developmental stage, particularly in Intelligent Transportation Systems applications. For example, operational tests have been completed that use in-vehicle navigation systems and electronic mapping systems to provide real-time traffic information to drivers. Loran-C has been used for automatic vehicle location for bus scheduling. Operational tests are either planned or in progress to use radionavigation for route guidance, in-vehicle navigation, providing real-time traffic information to traffic information centers, and improving emergency response. Several transit operational tests will use automatic vehicle location for automated dispatch, vehicle re-routing, schedule adherence, and traffic signal pre-emption. Examples include the use of Loran-C for vehicle location and dispatch. Loran-C, GPS, and dead-reckoning map-matching are being developed as systems that could take advantage of radionavigation systems and at the same time improve safety and efficiency of land navigation.

Although most operational tests plan to use GPS as the primary source of vehicle location information, other viable alternatives include microwave and infrared beacons, triangulation from broadcast stations, and vehicle location using cellular radio transmissions.

3.1.4 Uses Other Than Navigation

These uses are concerned primarily with the application of GPS, Loran-C, and Omega for radiolocation and surveying, time and frequency dissemination, and meteorological upper-air observations. Many other uses of GPS and augmented GPS are anticipated for Federal, state, and local governments, industry, and consumers. As with land navigation, the Government does not have a responsibility under law to provide radionavigation systems for these users. However, these applications represent a large (and growing) percentage of the civil radionavigation user community.

3.1.5 Space Navigation

There are numerous uses of GPS for space navigation; many are discussed in Section 2.7. Several spacecraft, including the International Space Station, the Space Shuttle, TOPEX/POSEIDON, ARISTOTELES, and the small satellites Lewis and Clark are using or will be using GPS for navigation. Some of these spacecraft will use GPS for support of instrument pointing, scientific data processing, and, in the case of the Space Shuttle, during approach and landing as well as on orbit and during ascent.

3.2 Existing and Developing Systems - Status and Plans

3.2.1 Loran-C

Loran-C was developed to provide military users with a radionavigation capability having much greater coverage and accuracy than its predecessor (Loran-A). It was subsequently selected as the Federally provided radionavigation system for civil marine use in the U.S. coastal areas. It is now designated by the FAA as a supplemental system in the NAS.

A. Operating Plan

Loran-C was designated as the Federally provided navigation system for the U.S. coastal areas in 1974. Implementation of the program authorized at that time has been completed. Studies have shown that further expansion is not cost-beneficial. The domestic Loran-C system as it is operated and supported by the USCG as of January 1, 1995 will consist of 29 transmitting stations comprising 12 Loran-C chains. Included in this count is the Russian-American chain and the East Newfoundland Loran-C chain. The former is a joint chain operated with Russia; the latter is a Canadian chain which was developed to return Loran-C to portions of the area previously covered by the Labrador Sea chain.

Current use of the Loran-C system appears to be leveling off and will most likely decrease as GPS and DGPS equipment fills the market place. This trend is expected to continue unless user equipment is developed that will take advantage of the two systems; i.e., Loran-C and GPS have no common vulnerabilities as they would apply to jamming, spoofing and interference. However, given the expected decrease in use, the estimated time frame for continued need of Loran-C in the U.S. has been reduced to the year 2000. Accordingly, the USCG has suspended its Loran-C equipment recapitalization program. The remaining initiatives include replacement of older transmitters in Alaska, the introduction of the automatic blink system, and consolidating the control of Loran-C. It remains unclear at this time if any equipment changes necessary to automate the synchronization of Master stations to UTC will be implemented.

Figure 3-1 outlines the operating plan for the Loran-C system. The coverage is shown in Appendix A.

B. User Community

Initially, the major user of Loran-C was the military, since civil marine use was limited due to the high cost of Loran-C receivers and the lack of coverage over much of the U.S. coastal areas. Technological advances rapidly lowered user receiver costs, and coastal coverage limitations have been eliminated by system improvements and expansion. As a result, there is presently extensive civil marine and aviation use of Loran-C. In addition, there is growing terrestrial use in radiolocation, vehicle tracking, and precise time/time interval and frequency applications. The meteorological community uses Loran-C based upper air observation systems.

C. Acceptance and Use

Up to the present, users of Loran-C have been one of the largest communities employing a single radionavigation system. This situation is changing now that GPS has achieved initial operational capability and GPS user equipment continues to drop in price. Traditionally, the primary users of Loran-C were the maritime community operating in the coastal phase and, in certain parts of the world, in the oceanic phase of marine navigation. In the few years preceding the expansion of Loran-C to the mid-continent regions of the United States, the aviation, time and frequency and terrestrial uses of Loran-C became recognized. Use of the system is expected to remain constant with little to no growth anticipated in the near term. As existing Loran-C user equipment becomes outdated, it is anticipated that users will purchase GPS, or augmented GPS equipment and begin the transition away from Loran-C.

D. Outlook

Other countries are developing and continuing Loran-C to meet their future navigational needs. Many of these initiatives have taken place as a result of the termination of the U.S. DOD requirement for overseas Loran-C. This need came to an end as of December 31, 1994. With the introduction of GPS, many countries have decided that it is in their own best interests not to have their navigational needs met entirely by a U.S. DOD-controlled navigation system. To preclude a potential situation (real or perceived) where GPS could be further degraded to meet U.S.

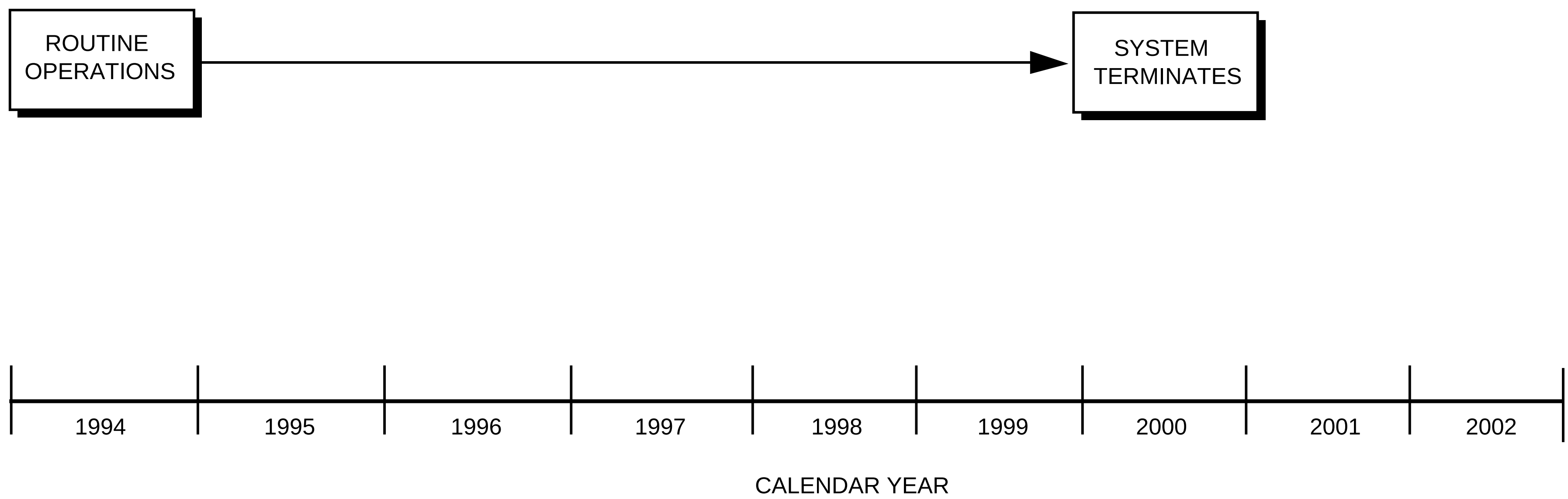


Figure 3-1. Operating Plan for Loran-C

defense objectives, these countries have opted to take on the responsibility to continue Loran-C.

Many of these initiatives have resulted in multilateral agreements between countries which have common navigational interests in those geographic areas where Loran-C previously existed to meet U.S. DOD requirements (e.g., Northern Europe, the Mediterranean and the Far East). In each of these cases, Russia has taken a significant interest in continuing its work for the integration into future chains of its Loran-C equivalent (Chayka). The IALA is taking a key role in facilitating the planned expansion of Loran-C in each of these areas. In Europe, the European Union has endorsed Loran-C as the terrestrial system of choice for maritime use into the next century.

Other nations which have their own loran chains are France (in the rho-rho or ranging mode), the People's Republic of China, Saudi Arabia, and India. It is projected that by January 1, 1995, there will be a total of 34 Loran-C chains covering much of the terrestrial and surrounding maritime regions of the Northern Hemisphere.

3.2.2 Omega

The Omega system was developed and implemented by the Department of the Navy, with the assistance of the USCG and with the participation of several partner nations. It provides worldwide, all-weather radionavigation capability to air and surface users. The U.S. responsibility for operation of the system rests with the USCG.

A. Operating Plan

The eight-station Omega configuration has been operational since August 1982, although, in earlier configurations, the system was widely used for more than five years before this date. Omega stations are located in Norway, Liberia, North Dakota, Hawaii, La Reunion Island, Argentina, Australia, and Japan. The USCG operates the two stations located in the U.S. Bilateral agreements between the U.S. and the partner nations govern partner-nation operation, and the varying amounts of technical and logistic support. The USCG has operational control of the system; the International Omega Technical Commission (IOTC), which is composed of one representative from the operating agency of each country involved with the Omega system, is the forum for consultation regarding operational maintenance of Omega. Figure 3-2 outlines the operating plan for the Omega system.

B. User Community

In addition to the DOD air and marine users, civil ships and aircraft are using the Omega system. A number of air carriers and general aviation aircraft operators have received approval to use Omega as an update for their self-contained systems or as a primary means of navigation on oceanic routes. Receiver innovations have led to the use of very low frequency (VLF) communications transmissions to augment the

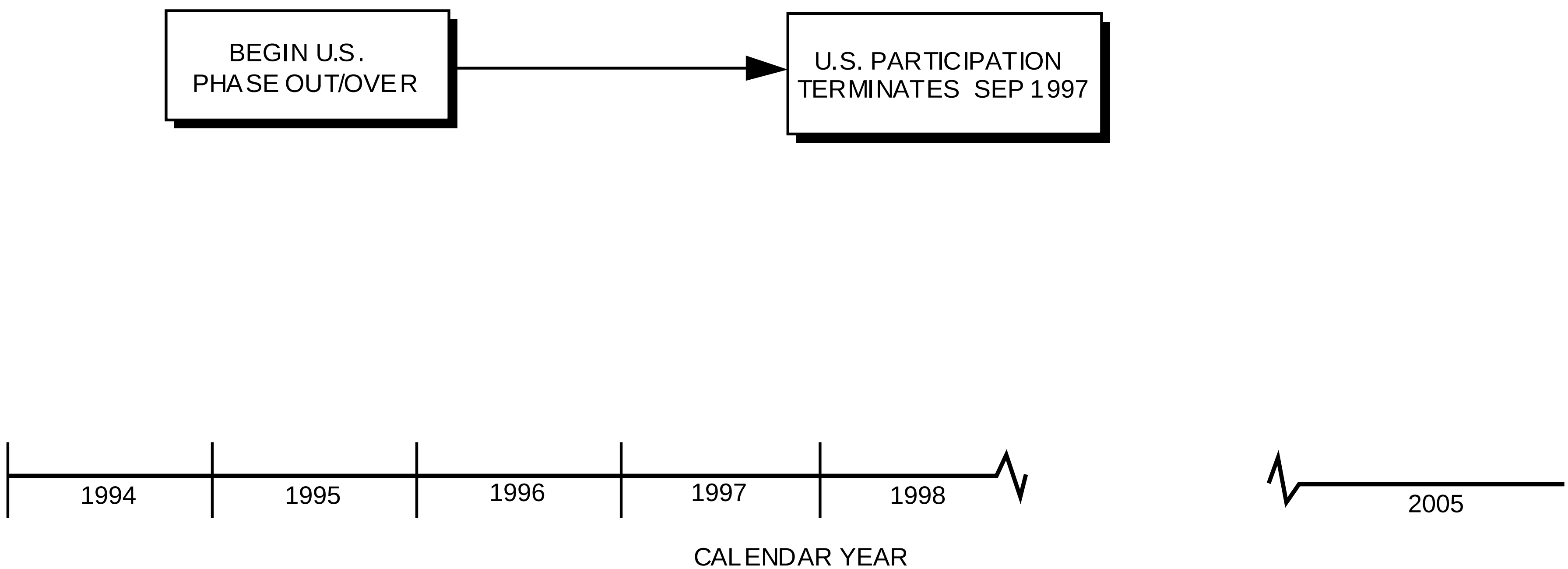


Figure 3-2. Operating Plan for Omega

Omega network and improve overall system redundancy and reliability; however, the U.S. Navy has emphasized that VLF communication signals are not intended for navigation purposes and that the use of these signals for navigation is at the risk of the user. Receivers designed to use VLF communication signals as part of the navigation solution should be capable, using Omega signals only, of meeting performance standards contained in FAA Advisory Circular 20-101C and Technical Standard Order TSO-C120.

Guidelines for the transmission of differential Omega corrections were established by the Inter-governmental Maritime Consultative Organization (now known as the International Maritime Organization - IMO) in Resolution A.425 (XI), "Differential Omega Correction Transmitting Stations," dated November 15, 1979.

C. Acceptance and Use

Because of its worldwide coverage, international civil use of Omega includes trans-oceanic shipping and aircraft navigation. It is also approved by the FAA for use as a supplement for domestic high altitude en route airspace navigation.

The precise timing aspects of Omega make it possible to obtain profiles of wind speed and direction from ground level to over 30 km with an Omega-based meteorological upper-air observation system. Over 200,000 Omega-equipped meteorological sondes are launched annually from approximately 550 locations around the world.

Current information indicates that the present Omega system covers nearly 100 percent of the Earth's surface. Signal coverage and system accuracy have been validated on a regional basis. The data collected from 22 fixed monitor receiver sites, shipboard monitor receivers, and aircraft receivers are being used to correct propagation models and tables and to confirm propagation parameters affecting signal coverage and availability. Results obtained from the validation effort have shown that the Omega system is meeting published performance. Validations began in the mid-1970s, and have been completed in the North Atlantic, North Pacific, South Atlantic, South Pacific, and Indian Oceans as well as the Mediterranean Sea. Accuracy of the Omega system is limited due to signal propagation characteristics and restrictions on signal selection when in close proximity to transmitting sites. For these reasons, Omega does not meet navigation requirements for vessels in U.S. coastal waters, or for aircraft flying in U.S. terminal airspace.

D. Outlook

Replacement of the timing and control equipment at transmitting stations is in progress. Other efforts are focused on, and dominated by, the transmitting antennas, particularly those in Hawaii and Norway. In addition, the USCG continues to improve user services and system performance. This includes coverage prediction programs, propagation models, and signal timing synchronization efforts.

Because of the international character of the system and international user acceptance, operational decisions regarding system life must be coordinated with the partner nations. The DOD requirement terminated in 1994; however, limited Service use is expected while the system remains operational and receiver maintenance is cost effective. For example, in response to a Congressional mandate, the U.S. Air Force Reserve's 53rd Weather Reconnaissance Squadron will continue to use an Omega-based dropwindsonde system to provide hurricane reconnaissance observations in support of the hurricane warning responsibilities of the National Weather Service's National Hurricane Center—a Department of Commerce activity.

With the achievement of GPS IOC in December 1993, the approval of GPS to meet aviation requirements currently met by Omega is imminent. It is anticipated that aviation users will quickly transition from Omega to GPS due to its accuracy and rapidly dropping equipment prices. Mariners are already using GPS for oceanic navigation. Because the U.S. navigation needs for Omega will be met by GPS, and Omega use is declining rapidly, continuation of U.S. participation in Omega beyond September 30, 1997 will depend on the financial support of the system by timing and weather users. The Government of Australia has projected that it will terminate operations at its Omega station on September 30, 1997.

3.2.3 VOR and VOR/DME

VOR was developed as a replacement for the Low-Frequency Radio Range to provide a bearing from an aircraft to the VOR transmitter. A collocated DME provides the distance from the aircraft to the DME transmitter. At most sites, the DME function is provided by the TACAN system which also provides azimuth guidance to military users. Such combined facilities are called VORTAC stations. Some VOR stations are used for the scheduled broadcast of weather information.

A. Operating Plan

The FAA operates 1012 VOR, VOR/DME, and VORTAC stations including 150 VOR-only stations. The number of stations is expected to remain stable until the VOR/DMEs begin to be decommissioned in 2005. The DOD also operates stations in the U.S. and overseas that are available to all users. The operating plan for VOR and VOR/DME is shown in Figure 3-3.

B. User Community

Approximately 85 percent of general aviation aircraft are equipped with at least one VOR receiver and over 50 percent of the aircraft have two or more VOR receivers. All air carrier aircraft depend on it for bearing information. DME is used to provide distance information for all U.S. air carrier aircraft and for a large number of general aviation and military aircraft operating in U.S. airspace.

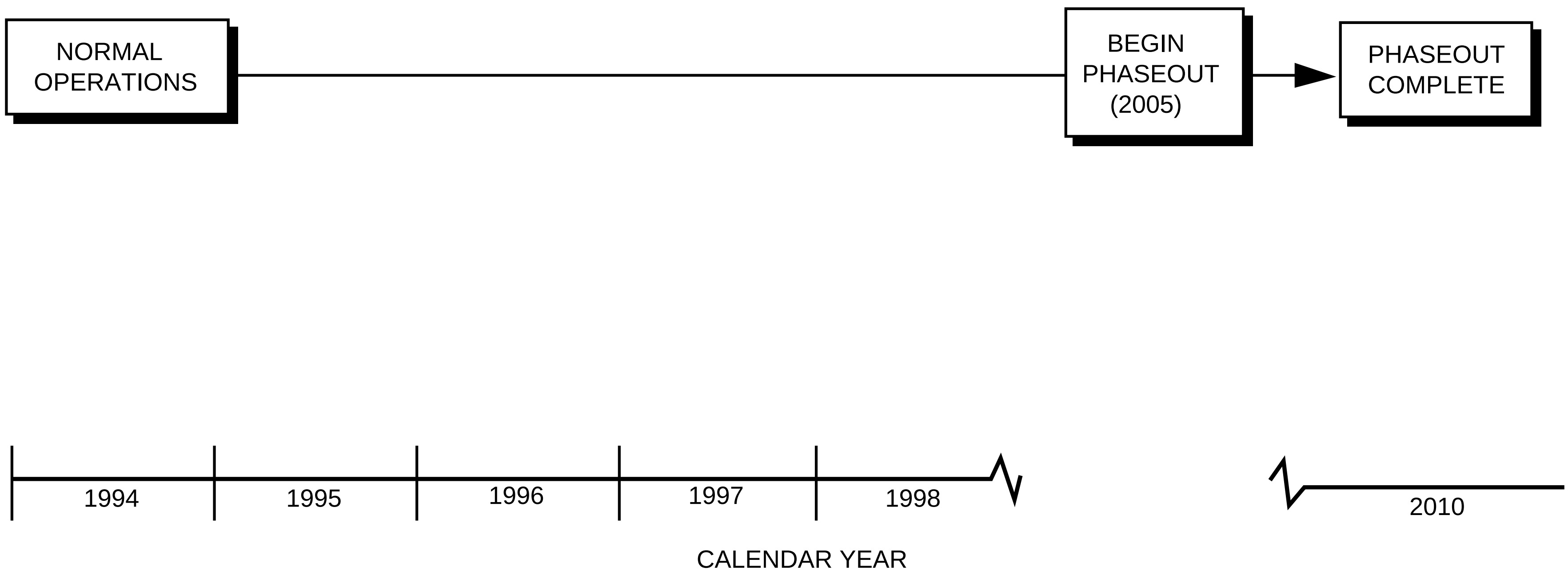


Figure 3-3. Operating Plan for VOR and VOR/DME (Based on GPS/WAAS Operational Date)

C. Acceptance and Use

VOR is the primary radionavigation aid in the National Airspace System and is the internationally designated standard short-distance radionavigation aid for air carrier and general aviation IFR operations. It is easy to use and is generally liked by pilots. Because it forms the basis for defining the airways, its use is an integral part of the air traffic control procedures.

D. Outlook

A small increase in the number of users equipped with VOR is expected over the next several years due to an increase in the aircraft population operating in the U.S. During this time, many users that are equipping their aircraft for VFR operation may choose to equip with GPS in preference to VOR. VOR/DME will still be required for IFR flight until the WAAS is approved for primary means navigation. It is then expected that VOR equipage will begin to rapidly decrease.

The current VOR/DME network will be maintained until 2005 to enable aircraft to become equipped with WAAS avionics and to allow the aviation community to become familiar with the system. Plans for expansion of the network are limited to site modernization or facility relocation, and the conversion of sub-standard VORs to a Doppler VOR configuration. The phaseout of the VOR/DME network is expected to begin in 2005 and to be complete by 2010.

The target date for phase-out of the DOD requirement for VOR and VOR/DME is the year 2000. In the case of a military VORTAC site that has developed an appreciable civilian-use community and is due for phase-out, transfer of operational responsibility to the DOT will be discussed between DOD and DOT.

3.2.4 TACAN

TACAN is a UHF radionavigation system which provides a pilot with relative bearing and distance to a beacon on the ground, a ship, or to specially equipped aircraft. TACAN is the primary tactical air navigation system for the military services ashore and afloat. TACAN is often collocated with the civil VOR stations (VORTAC facilities) to permit military aircraft to operate in civil airspace.

A. Operating Plan

DOD presently operates 173 TACAN beacons and the FAA operates 640 TACAN beacons for DOD. Present TACAN coverage ashore will be maintained until phased out in favor of GPS. However, GPS without enhancement cannot replace the TACAN function afloat (moving platforms). Civil DME and the distance-measuring functions of TACAN will continue to be the same. The operating plan for TACAN is shown in Figure 3-4.

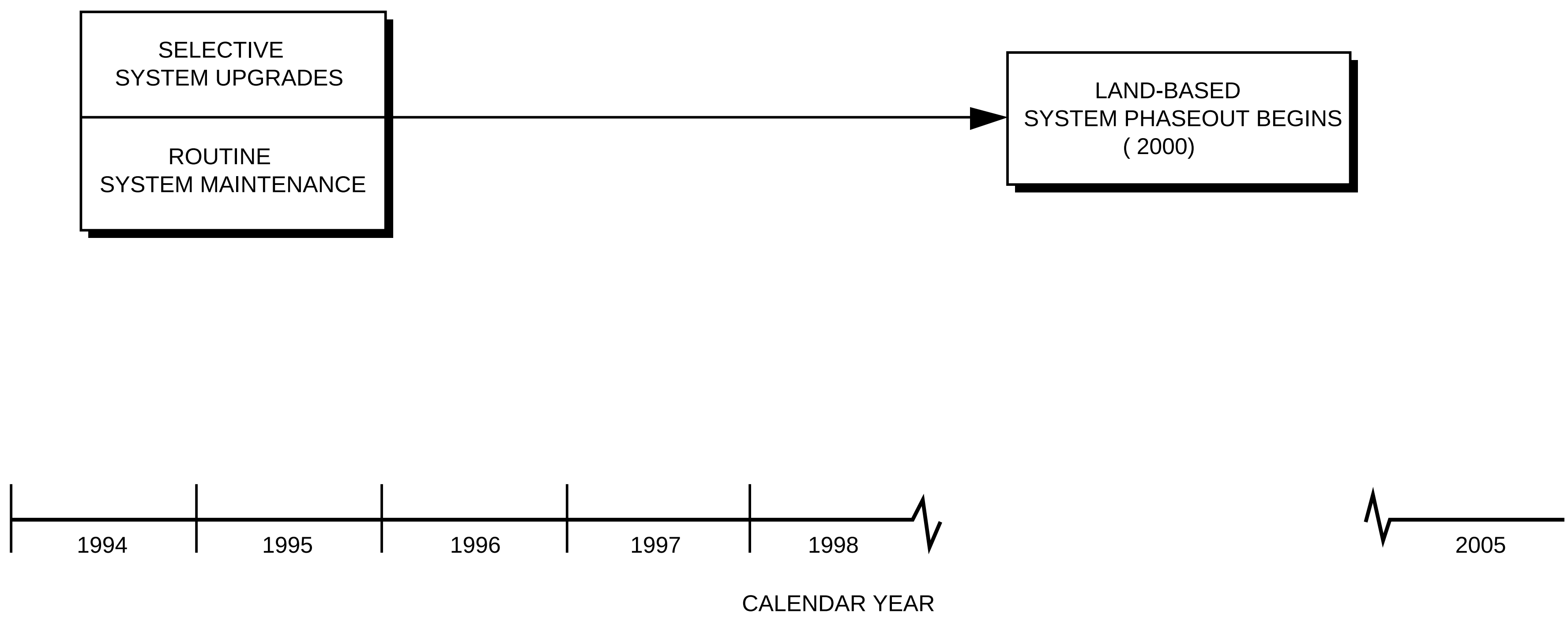


Figure 3-4. Operating Plan for TACAN

B. User Community

There are presently approximately 14,500 aircraft which are equipped to determine bearing and distance to TACAN beacons. These consist primarily of Navy, Air Force, and to a lesser extent, Army aircraft. Additionally, allied and third world military aircraft use TACAN extensively. NATO has standardized on TACAN until 1995.

C. Acceptance and Use

TACAN is used by DOD and NATO aircraft operating under IFR ashore and IFR and VFR for tactical and en route navigation afloat. TACAN provides range and azimuth information and is easy to use.

Because of propagation characteristics and radiated power, TACAN is limited to line-of-sight and is limited to approximately 180 miles at higher altitudes. As with VOR/DME, special consideration must be given to location of ground-based TACAN facilities, especially in areas where mountainous terrain is involved due to its line-of-sight coverage.

D. Outlook

The DOD requirement for and use of land-based TACAN will terminate when aircraft are properly integrated with GPS and when GPS is certified to meet RNP in national and international controlled airspace. Any decommissioning of TACAN facilities will take place by mutual agreement between FAA and DOD. The target date to begin phaseout of TACAN services is 2000. The DOD plans to complete GPS integration by 2000. In order to satisfy projected RNP criteria, some current DOD GPS user equipment will require modification. The expected completion date for this modification effort is no later than 2005. The requirement for shipboard TACAN will continue until a suitable replacement is operational.

3.2.5 ILS

ILS provides aircraft with precision vertical and lateral navigation (guidance) information during approach and landing. Associated marker beacons or DME equipment identify the final approach fix, the point where the final descent to the runway is initiated.

A. Operating Plan

The FAA operates nearly 900 ILS systems in the NAS, of which 81 are Category II or Category III systems. In addition, the DOD operates 165 ILS facilities in the U.S. New ILS sites may be installed prior to the availability of precision approaches using the WAAS if they are cost-beneficial. The operating plan is shown in Figure 3-5.

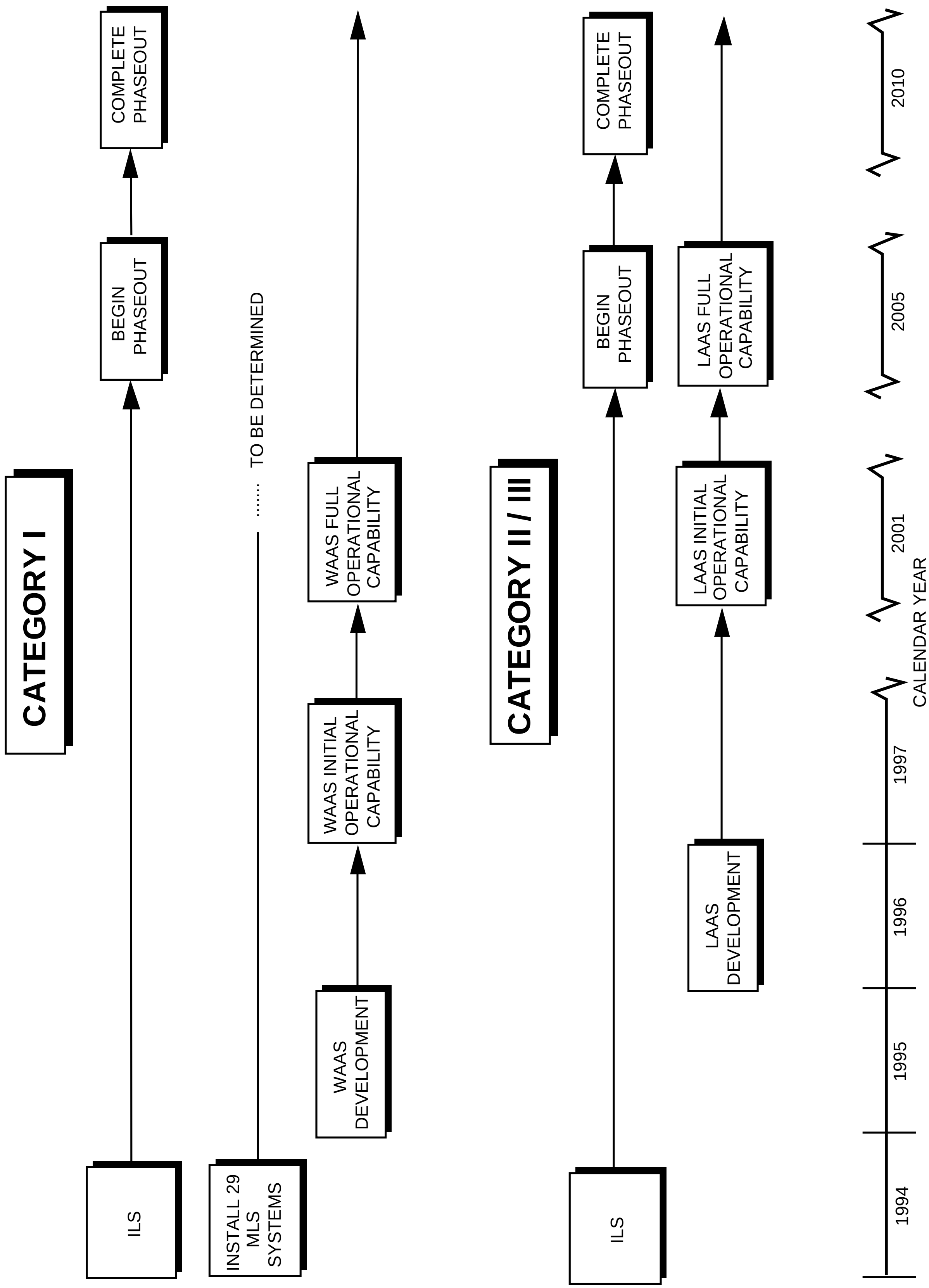


Figure 3-5. Operating Plan for Precision Landing Systems

B. User Community

Federal regulations require U.S. air carrier aircraft to be equipped with ILS avionics. It is also extensively used by general aviation aircraft. Since ILS is the ICAO standard landing system, it is extensively used by air carrier and general aviation aircraft of other countries.

C. Acceptance and Use

A slight increase in the number of users equipped with ILS is expected over the next several years due to an increase in the aircraft population operating in the U.S. ILS equipage rates are then expected to rapidly decrease once the WAAS is approved for Category I approaches.

D. Outlook

User Base Expansion: Based on a 1991 user survey, the number of civil aircraft equipped with ILS is estimated to be 124,000. This number is expected to increase until the GPS WAAS becomes operational and gains user acceptance.

Expected System Life: ILS is the standard civil landing system in the U.S. and abroad, and is protected by ICAO agreement to January 1, 1998. ICAO has selected the MLS as the international standard precision approach system, with implementation targeted for 1998. The U.S. will continue to work with ICAO Member States to review the ICAO ILS/MLS transition plan in light of new technologies. This transition plan will be revisited at ICAO's Special Communications/Operations Divisional Meeting scheduled for March 1995. The FAA will provide the latest results of its R&D efforts on the use of satellite technology for precision approaches and landing at that meeting.

ILS will remain the primary system for Category I precision approaches until 2001 when the WAAS is expected to be designated as a primary Category I service. ILS will remain in service together with WAAS precision approaches to allow users an opportunity to equip with WAAS receivers and to become comfortable with its service. The phaseout of Category I ILS is expected to begin in 2005 and to be complete by 2010.

For Category II/III precision approaches, test results show that a GPS-based system promises to deliver this level of service in a more cost-effective manner than ILS. Because of these results, the first GPS-based Category II/III systems are anticipated to be introduced into the NAS by 2001, collocated at existing Category II/III sites. The phaseout of Category II/III ILS from the NAS is then expected to begin in 2005 and to be complete by 2010.

System Limitations: ILS limitations manifest themselves in three major areas:

1. Performance of individual systems can be affected by terrain and man-made obstacles, e.g., buildings and surface objects such as taxiing aircraft and snowbanks. These items may impose permanent use constraints on individual systems or limit their use at certain times.

2. The straight-line approach path inherent in ILS constrains airport operations to a single approach ground track for each runway. In contrast, both GPS and MLS will allow multiple ground track paths for approaches to the active runway as well as provide a steeper glide slope capability for Short Take-Off and Landing (STOL) aircraft.

3. Even though the new 50 kHz frequency spacing has doubled the ILS channel availability, frequency saturation limits the number of systems that can be installed. Frequency saturation occurs when ILS facilities, in close proximity with inadequate frequency separation, produce mutual interference.

3.2.6 MLS

A limited procurement of Category I MLS equipment was initiated in 1992. However, the FAA has determined that augmented GPS is feasible for Category I precision approach operations and is progressing toward implementation and certification. Only 29 Category I MLS systems are currently planned to be installed, and the FAA has terminated the development of Category II and III MLS equipment.

The termination of the Category II and III development contracts was primarily a budget decision, supported by initial results of R&D efforts that have demonstrated the potential for using augmented GPS technology for this application. The FAA retains the option to purchase MLS for Category II and III operations on the open market should the decision be made to implement MLS in the future.

A. Operating Plan

The operating plan for the 29 Category I MLS systems is shown in Figure 3-5.

B. User Community

MLS applications are limited to aviation. The U.S. does not plan at this time to install MLS except where required by treaty.

C. Acceptance and Use

MLS does not have the siting problems of ILS and offers higher accuracy and greater flexibility, permitting precision approaches at more airports. MLS provides DOD tactical flexibility due to its ease in siting and adaptability to mobile operations. However, there is limited user support for MLS in the U.S.

D. Outlook

Unless required by treaty, little use of MLS is anticipated in the U.S.

3.2.7 Transit

The Navy Navigation Satellite System (NNSS), also referred to as Transit, is a satellite-based positioning system which provides submarines, surface ships, and a few specially equipped aircraft with an accurate two-dimensional positioning capability. The Transit system consists of low-altitude satellites in near polar orbits, ground-based monitor stations to track the satellites, and injection facilities to update satellite orbital parameters.

Developed to support the Navy Fleet Ballistic Missile Submarines, Transit is now installed on domestic and foreign commercial vessels in addition to military surface vessels.

A. Operating Plan

DOD plans to operate Transit until December 1996. Ground-based monitor and injection facilities and satellites will be operated and supported by the Navy.

The current Transit constellation contains seven satellites. Five satellites are operational and two satellites are stored in orbit.

The Transit launch program ended in 1988. The Navy will terminate operation of the system by the end of 1996. The operating plan is shown in Figure 3-6.

B. User Community

There are currently fewer than 200 military Transit users. Foreign and domestic commercial vessel use of the Transit system has far outpaced the DOD use. It is estimated that 80,000 sets were in commercial use at the end of 1987. Approximately 90 percent of all commercial Transit receiver sales are for the single channel receivers. Determination of precise position (surveying) has become an important use of Transit.

C. Acceptance and Use

Transit provides periodic, worldwide, position-fixing information for Navy ships and submarines and commercial ships, as well as land users. Use of Transit has declined in recent years due to the advent of GPS.

From a military viewpoint, Transit provides precise positioning for fixed and low dynamic vehicles (ships, submarines, and surveying). In a high dynamic, tactical environment (aircraft and missiles), Transit has little use since it is a Doppler system and small errors in user estimates of platform speed can cause large errors in user position. (One knot of unknown speed can cause a position error of 0.2 nm.)

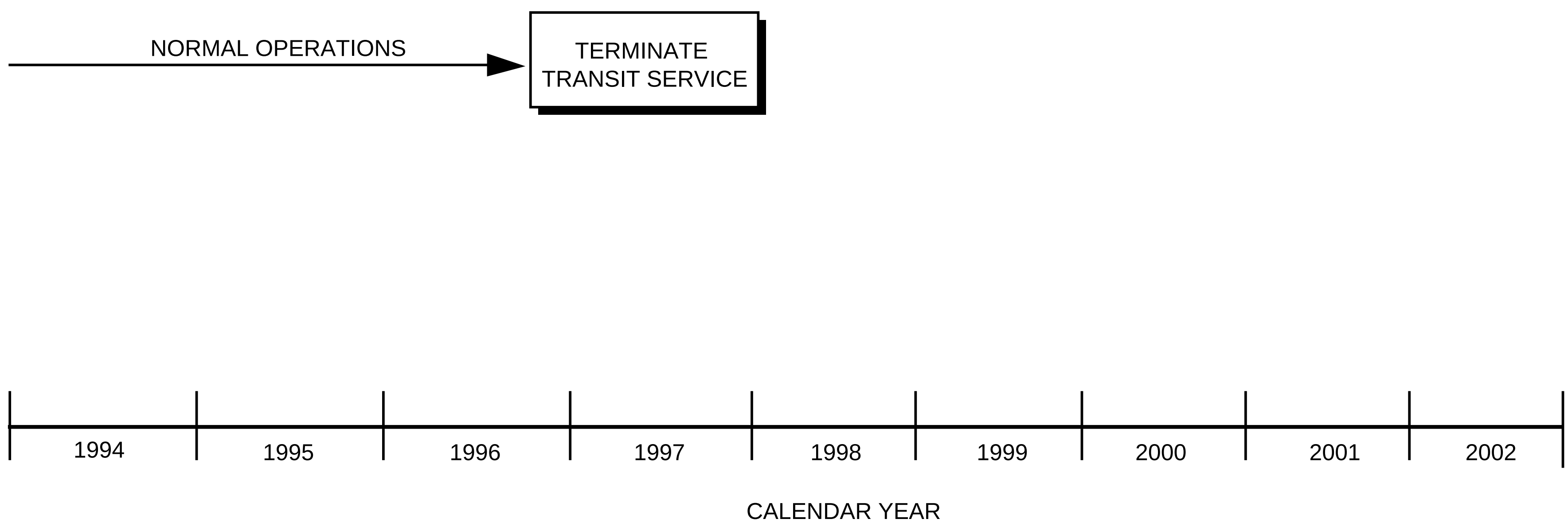


Figure 3-6. Operating Plan for Transit

D. Outlook

Transit will be replaced with GPS by 1996. Transit will not be operated by or transferred to a civilian agency of the U.S. Government.

3.2.8 Aeronautical Nondirectional Beacons (NDBs)

Aeronautical nondirectional beacons are used for transition from en route to precision terminal approach facilities and as nonprecision approach aids at many airports. In addition, some state and locally owned NDBs are used to provide weather information to pilots. In Alaska and in some remote areas, NDBs are also used as en route facilities. However, GPS and the FAA's automated weather observing system (AWOS) and automated surface observing system (ASOS) have begun to satisfy the requirement for NDBs.

A. Operating Plan

The FAA operates over 700 NDBs. This number is expected to decline steadily over the next decade due to the increasing popularity of GPS. In addition, there are about 200 military aeronautical beacons and 800 non-Federally operated aeronautical beacons. During the next 10 years, FAA expenditures for beacons are planned to be limited to the replacement of deteriorated components, modernization of selected facilities, and an occasional establishment or relocation of an NDB used for ILS transition. The operating plan is shown in Figure 3-7.

B. User Community

All air carrier, most military, and many general aviation aircraft carry automatic direction finders (ADF). However, the importance of ADF is expected to decline with the increasing popularity of GPS.

C. Acceptance and Use

Aircraft use radiobeacons as compass locators to aid in finding the initial approach point of an instrument landing system as well as for nonprecision approaches at low traffic airports without convenient VOR approaches.

The large number of general aviation aircraft that are equipped with radio direction finders attests to the wide acceptance of radiobeacons by the user community. The primary reason for this acceptance is that adequate accuracy can be achieved with low-cost user equipment. However, now that GPS-based nonprecision approaches are available, transition from the NDB network can begin.

D. Outlook

GPS today provides improved navigation service compared to NDBs at an acceptably low cost to the user. Therefore, the phaseout of NDBs is planned to begin in the year

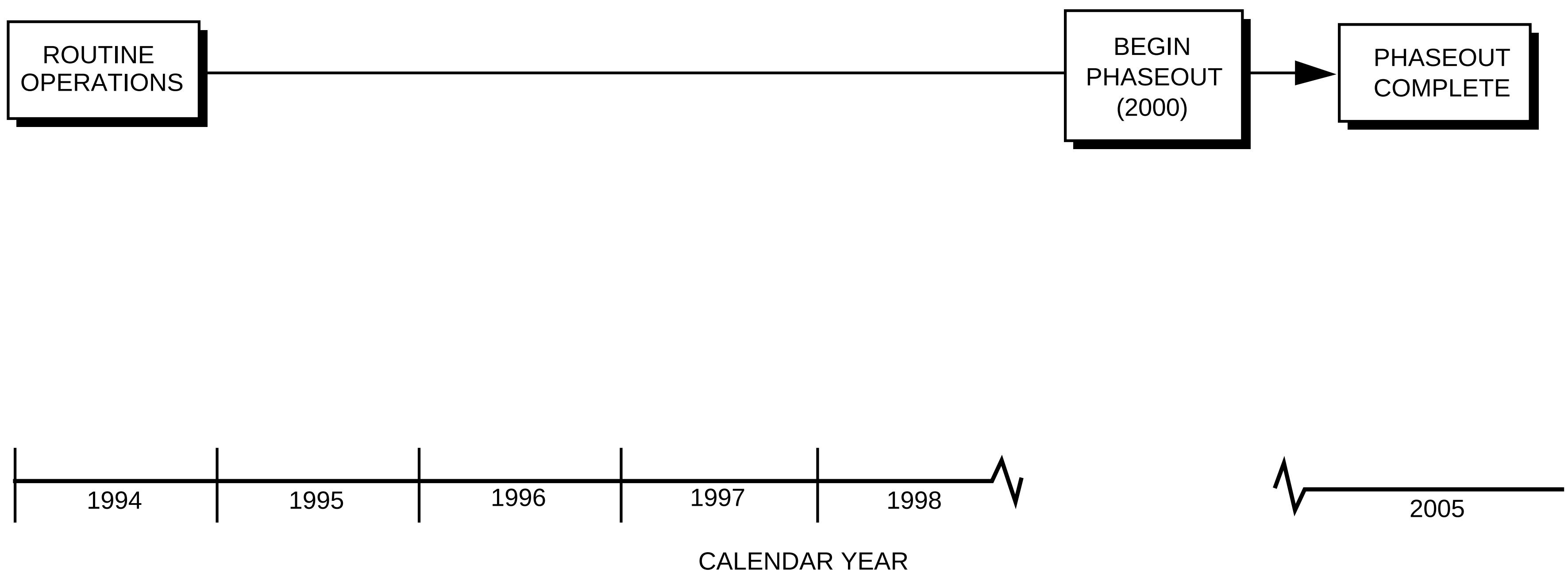


Figure 3-7. Operating Plan for Aeronautical Nondirectional Beacons (Based on GPS/WAAS Operational Date)

2000 and to be complete by 2005. In the interim, Federal expenditures for replacements and new establishments will be limited.

3.2.9 Maritime Radiobeacons

Maritime radiobeacons provide a backup to more sophisticated radionavigation systems and a low-cost, medium accuracy system for vessels equipped with only minimal radionavigation equipment. Use, however, is dwindling very rapidly.

A. Operating Plan

Approximately 85 maritime radiobeacons are operated by the USCG. The operating plan is shown in Figure 3-8. Selected maritime radiobeacons will be modified to broadcast DGPS corrections with the implementation of the USCG DGPS service.

B. User Community

Radiobeacons are primarily used as homing devices for recreational boaters, but they also act as a backup for those users having more sophisticated radionavigation capability. As selected radiobeacons are modified to broadcast DGPS corrections, those radiobeacons will become a primary element in the HHA and coastal phases of navigation, used by all vessels, and required for certain classes of vessels.

C. Acceptance and Use

Maritime radiobeacons have been an acceptable radionavigation tool for pleasure boaters using them for homing purposes, largely due to the adequate service with low-cost user equipment.

Marine radiobeacons provide a bearing accuracy relative to vehicle heading on the order of +3 to +10 degrees. This might be considered a systemic limitation but, in actual use, it is satisfactory for many navigational purposes. Radiobeacons are not satisfactory for marine navigation within restricted channels or harbors. They do not provide sufficient accuracy or coverage to be used as a primary aid to navigation for large vessels in U.S. coastal areas.

D. Outlook

Maritime radiobeacons have been used primarily by pleasure boaters in the homing mode. However, with the availability of low-cost Loran-C and GPS receivers that provide far more flexible use to the boater, the use of radiobeacons has been continually declining. As the USCG conducts evaluation of the need for beacons, those with no identifiable user base will be discontinued. Maritime radiobeacons not modified to carry DGPS correction signals are expected to be phased out by the year 2000.

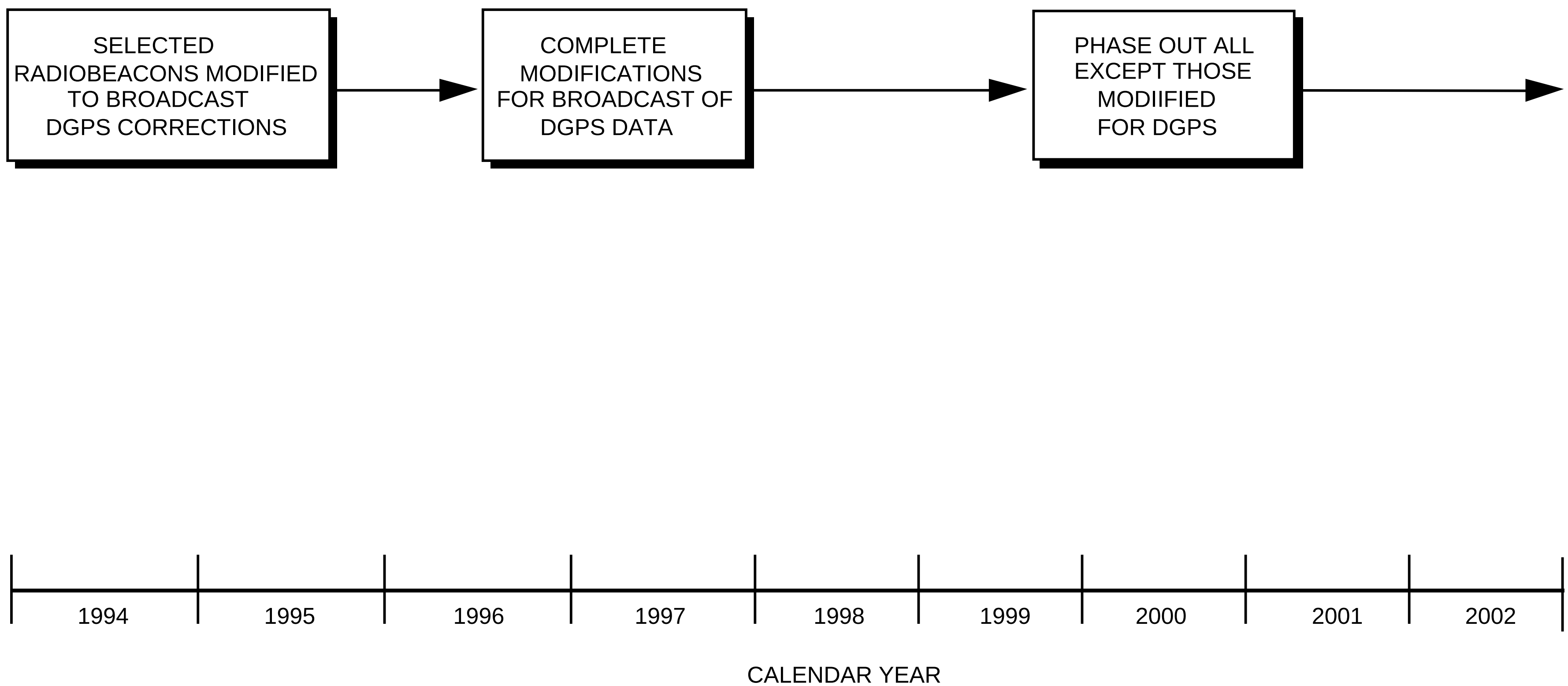


Figure 3-8. Operating Plan for Maritime Radiobeacons

The modulation of maritime radiobeacons with DGPS corrections will make these beacons unusable by digital aviation ADFs and may make their use by analog ADFs difficult.

Radar Transponder Beacons: Radar transponder beacons (RACONs) are short-range radio devices used to provide fixed radar reference points in areas where it is important to identify a special location. Currently, they are only used in the marine environment. Examples of the use of RACONs are: landfall identification; improvement of ranging to and identification of an inconspicuous coastline; improvement of identification of coastlines permitting good ranging but which are otherwise featureless; improvement of the identification of a particular aid to navigation in an area where many radar returns appear on the radar display; provision of a lead to a specific point such as into a channel or under a bridge; and warning to temporarily mark a new obstruction, or other uncharted or especially dangerous fixed hazard to navigation.

Though RACONs offer a unique possibility of positive aid identification, uncontrolled proliferation could lead to an unacceptable increase in responses presented on a ship's radar display. This could degrade the usefulness of the display and cause confusion. In 1986, the Code of Federal Regulations was changed (33 CFR 66.01-1 (d)) to allow private operation of RACONs with USCG approval. The USCG now has about 110 frequency agile RACONs.

3.2.10 Global Positioning System (GPS)

GPS is a space-based positioning, navigation, and time distribution system designed for worldwide military use. Special capabilities of particular interest to DOD include precise, continuous, all-weather, common-grid positioning, velocity and timing. Additionally, the weapon system enhancement features of the GPS can be denied to enemy forces, and the system has features to prevent spoofing and to reduce susceptibility to jamming. Although designed for military use, GPS is available for civil use at the highest accuracy consistent with U.S. national security interests.

A. Operating Plan

GPS will be the primary Federally-funded radionavigation system for the foreseeable future. An Initial Operational Capability (IOC) was declared December 8, 1993 when the DOD determined that the SPS, described in memoranda of agreement between the DOD and DOT, could be sustained. The USCG and FAA subsequently authorized GPS for civil transportation use. DOD Full Operational Capability (FOC) is planned to occur in 1995 after the 24-satellite constellation has completed testing for military functionality (a milestone that does not have any significant impact on civil users).

All routine command and control functions are performed from the Master Control Station in Colorado Springs, Colorado using its dedicated network of remote monitor stations and ground antennas. The GPS constellation is configured and operated to provide the SPS signals to civil users in accordance with the *GPS Standard Positioning Service Signal Specification* (available through the U.S. Government Printing Office and the USCG Navigation Information Service).

The DOD will maintain a 24-satellite constellation. Additional satellites will be launched on an expected failure strategy (an additional satellite is launched when there are indications that a satellite should be replaced).

The operating plan for GPS is shown in Figure 3-9.

B. User Community

The GPS user community has grown exponentially in the past two years and that growth is expected to continue. Rapid growth has occurred in all modes of transportation. Non-transportation use is also growing at a rapid rate and includes users employed in surveying, farming, resource exploration, and law enforcement. Because of security considerations, the GPS Precise Positioning Service (PPS) is restricted to U.S. Armed Forces, U.S. Federal agencies, and selected allied Armed Forces and governments. While GPS/PPS has been designed primarily for military radionavigation needs, it will nevertheless be made available on a very selective basis to U.S. and foreign private sector (non-governmental) civil organizations. Access determinations will be made by the Government on a case-by-case evaluation that:

- Access is in the U.S. national interest.
- There are no other means reasonably available to the civil user to obtain a capability equivalent to that provided by GPS/PPS.
- Security requirements can be met.

The DOT has established the Civil GPS Service (CGS), consisting of the GPS Information Center (GPSIC) (now part of the USCG's Navigation Information Service) and the PPS Program Office (PPSPO). The GPSIC provides information to and is the point of contact for civil users of the GPS system (see Appendix A). The PPSPO administers GPS/PPS service to approved users. Civil users requesting access to the GPS/PPS must submit their applications through the PPSPO. In addition, the DOD and DOT have agreed that representatives from the DOT will be located within the Master Control Station and at the GPS Joint Program Office to participate in the day-to-day system operations, system development, and future requirements definitions.

Any planned disruption of the SPS in peacetime will be subject to a minimum of 48-hour advance notice provided by the DOD to the USCG GPSIC and the FAA Notice to Airman (NOTAM) system. A disruption is defined as periods in which the GPS is not capable of providing SPS as specified in the *GPS Standard Positioning Service Signal Specification.* Unplanned system outages resulting from system

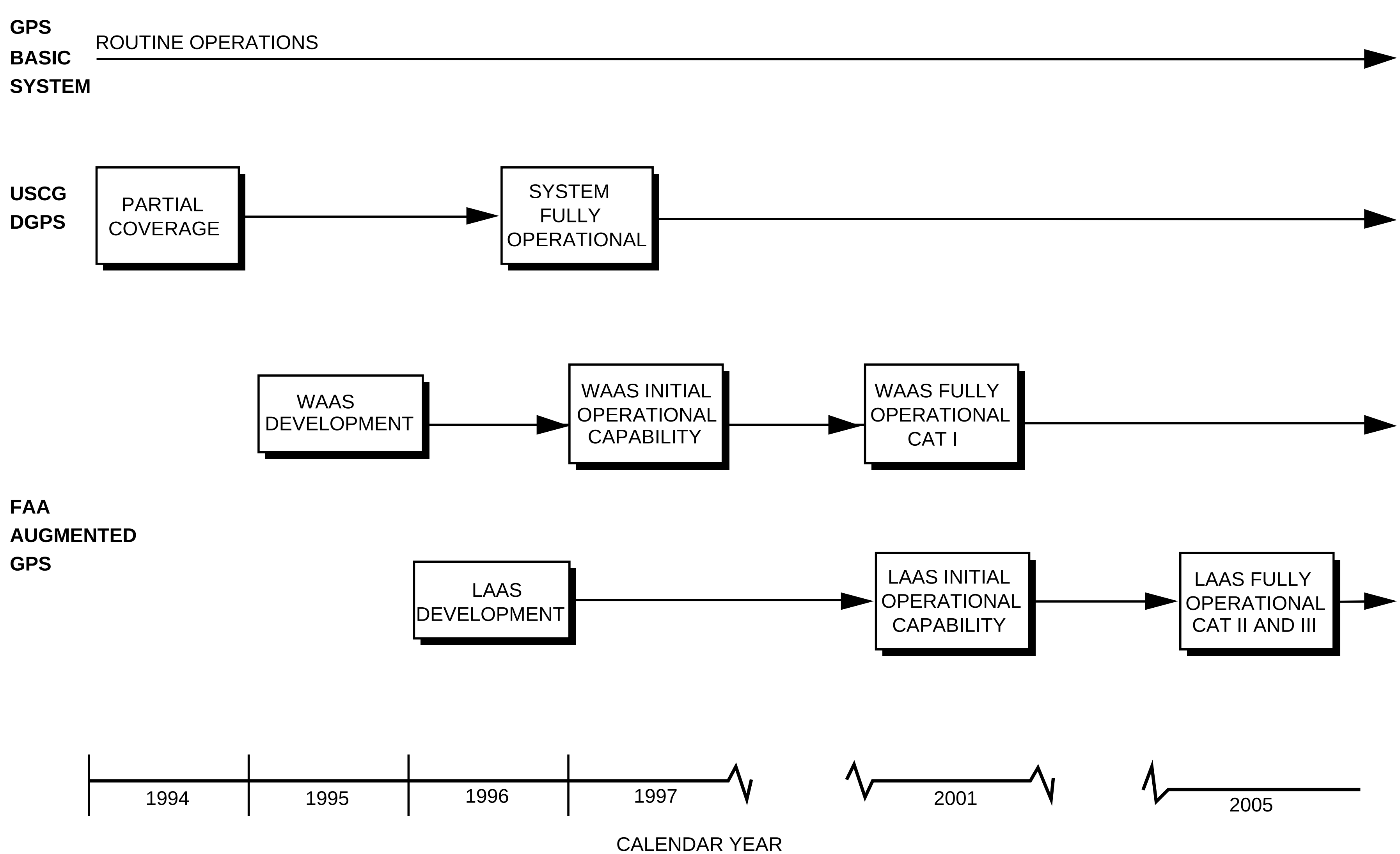


Figure 3-9. Operating Plan for GPS/Augmented GPS

malfunctions or unscheduled maintenance will be announced by the GPSIC and NOTAM systems as they become known.

C. Acceptance and Use

The following list is a sampling of current or likely future uses of GPS as GPS technology replaces earlier less accurate or more costly methods.

Aviation

- Possible future use as a primary means of en route navigation and precision landing and takeoff.
- Current use for supplemental en route navigation.
- Monitor wing deflections in flight.
- Precise location of airfields and landing aids.

Environmental Protection

- Hazardous waste site investigation.
- Ground mapping of ecosystems.
- Oil spill tracking and cleanup.

Highway

- Intelligent Transportation Systems traffic management.
- Highway facility inventory and management.
- Highway construction.
- Navigation for motor vehicle drivers.
- Truck fleet on-the-road management.
- Bus fleet on-the-road management.
- Monitoring status of bridges.

Maritime and Waterways

- Navigation on the high seas.
- Harbor approach navigation.
- Harbor facility management.
- Dredging of harbors and waterways.
- Positioning of buoys and marine nav-aids.
- Navigation for recreational vessels.
- Location of fishing traps and gear.
- Offshore drilling research.
- Monitoring deflections in dams as a result of hydrostatic and thermal stress changes.

Communications

- Precise timing for interlacing messages.

Railroad

- Railroad fleet monitoring.
- Train control and collision avoidance.
- Facility inventory and management.

Surveying

- Use as an electronic bench marker providing absolute geographic reference of latitude, longitude, and altitude.
- Measuring areas without triangulation.
- Oil and mineral prospecting.
- National Spatial Data Infrastructure.

Recreation

- Hiking and mountain climbing.

Law Enforcement and Emergency Response

- Tracking and recovering stolen vehicles.
- Tracking criminal and contraband movements.
- Maintaining security of high government officials and dignitaries while traveling.
- Border surveillance.
- Location identification for ambulance and fire departments.

Weather, Scientific and Space

- For upper-air observation of atmospheric parameters, such as wind speed and direction, pressure, and humidity.
- Measurement of sea level from satellites.
- Navigating and controlling space shuttle.
- Placing satellites into orbit.
- Monitoring earthquake areas and tectonic plate movements.

Agriculture and Forestry

- Forest area and timber estimates.
- Identifying habitats.
- Fire perimeters.
- Water resources.
- Property boundaries.

D. Outlook

The basic GPS will be augmented to satisfy remaining transportation requirements, particularly precision approach to aircraft landing and ship harbor operations.

3.2.11 GPS Augmentations

Unaugmented GPS will not meet all performance requirements for aviation or for the harbor/harbor approach phase of marine navigation. For example, an aircraft must have at least five satellites in view above a mask angle of 7.5 degrees in order to provide receiver autonomous integrity monitoring (RAIM). This condition is not always satisfied with the existing GPS constellation, resulting in so-called "RAIM holes" and limiting GPS to use as a supplemental navigation system. Some type of augmentation is required for GPS to meet the RNP of an airspace.

GPS may exhibit variances from a predicted grid established for navigation, charting, or derivation of guidance information. This variance may be caused by propagation anomalies, errors in geodesy, accidental perturbations of signal timing, and the implementation of SA.

Adverse effects of these variances may be substantially reduced, if not practically eliminated, by differential techniques. In such differential operation, a reference station is located at a fixed point (or points) within an area of interest. GPS signals are observed in real time and compared with signals expected to be observed at the fixed point. Differences between observed signals and predicted signals are transmitted to users as differential corrections to upgrade the precision and performance of the user's receiver.

The area over which corrections can be made from a single differential facility depends on a number of factors, including timeliness of correction dissemination, range of the correction transmission, area and uniformity of the system's grid, and user equipment implementations. A differential facility can serve an area with a radius of several hundred miles, depending on the system used and the method of implementation.

Recent innovations in carrier phase tracking differential GPS positioning systems have undergone considerable development and manufacturers are now providing DGPS receivers with carrier phase tracking capabilities. These systems are currently being used for obtaining centimeter accuracies with post processing of data by the U.S. Army Corps of Engineers and others. Similar systems are under development to provide real-time carrier phase tracking on dynamic platforms and will include on-the-fly initialization capabilities in the near future.

3.2.11.1 Maritime Differential GPS

The USCG plans to provide DGPS service for the harbor and harbor approach phase of maritime navigation. Maritime DGPS will use fixed GPS reference stations which will broadcast pseudo-range corrections using maritime radiobeacons. The USCG DGPS system will provide radionavigation accuracy better than 10 meters (2 drms) for U.S. harbor and harbor approach areas by 1996, free of charge to the user. Prototype USCG DGPS sites are achieving accuracies on the order of 1 meter. Until the DGPS service is declared operational by the USCG, users are cautioned that signal availability and accuracy are subject to change due to the dependence on GPS, testing of this developing service, and the uncertain reliability of prototype equipment.

Recommended standards for maritime DGPS corrections have been developed by the Radio Technical Commission for Maritime Services (RTCM) Special Committee 104. The USCG is represented on this subcommittee and is using the SC-104 standard for its DGPS system. There are DGPS reference stations available in the market today which are compatible with RTCM Special Committee 104 standard.

The operating plan for maritime DGPS is shown in Figure 3-9.

3.2.11.2 Aeronautical GPS Wide Area Augmentation System (WAAS)

The WAAS is a safety-critical system consisting of the equipment and software which augments GPS. The WAAS provides a signal in space to WAAS users to support en route through precision approach navigation. The WAAS users include all certified aircraft using the WAAS for any approved phase of flight. The signal in space provides three services: (1) integrity data on GPS and Geostationary Earth Orbit (GEO) satellites, (2) differential corrections of GPS and GEO satellites, and (3) a ranging capability.

The GPS satellite data is received and processed at widely dispersed sites, referred to as Wide-area Reference Stations (WRS). This data is forwarded to processing sites, referred to as Wide-area Master Stations (WMS), which process the data to determine the integrity, differential corrections, residual errors, and ionospheric information for each monitored satellite and generate GEO satellite parameters. This information is sent to a Ground Earth Station (GES) and uplinked along with the GEO navigation message to the GEO satellites. The GEO satellites downlink this data on the GPS L1 frequency with a modulation similar to that used by GPS.

In addition to providing GPS integrity, the WAAS verifies its own integrity and takes any necessary action to ensure that the system meets performance requirements. The WAAS also has a system operations and maintenance function that provides information to FAA maintenance personnel.

The FAA is conducting a major system acquisition consisting of the WAAS operational system and functional verification system. The program strategy is to quickly field an initial WAAS consisting of the basic requirements, and to enhance the system to meet the full WAAS requirements through a series of contract options. Implementation of the end-state WAAS will be accomplished in an evolutionary fashion over an estimated six-year period. The initial WAAS will include an initial operational system and a functional verification system. It will be upgraded through a series of pre-planned product improvements to eventually meet all the performance requirements of the WAAS end-state system.

A WAAS initial operational capability is expected in 1997 at which time users will be permitted to navigate with the system. Full operational capability is expected in 2001, at which time WAAS receivers will be certified for primary means of navigation. WAAS Category I precision approaches are anticipated to be introduced beginning in 1997, with as many as 8000 precision approaches expected to be available by 2001. The WAAS operating plan is shown in Figure 3-9.

Substantial benefits will accrue to both users and providers as the WAAS becomes operational and the aviation community transitions to WAAS avionics. Near-term user benefits will result from the use of a single navigation receiver that provides area navigation for all phases of flight and a ten-fold increase in runways approved for precision approaches. When combined with necessary improvements in air traffic control automation, additional user benefits are expected to be derived from reduced IFR separations and more efficient routings. Near-term provider benefits will be derived from the decommissioning of redundant navigation systems and more cost-effective instrument approaches. The WAAS is also expected to be used extensively for numerous other civil applications where improved accuracy, integrity and availability are needed.

3.2.12 Vessel Traffic Services (VTS)

Title 14 U.S.C. requires the USCG to safeguard the nation's ports, waterways, port facilities, vessels, persons, and property in the vicinity of the port from accidental or intentional destruction, damage, loss, or injury. These requirements are addressed by the USCG's Port Safety and Security Program, Marine Environmental Protection Program, and Waterways Management Program. In the course of administering these programs, the USCG assumes responsibility for vessel traffic management and navigation safety regulations. In responding to these requirements, and in furtherance of the National Transportation Plan, the USCG operates Vessel Traffic Services to provide active vessel traffic management in eight selected ports and waterways (see Figure 3-10).

The mission of VTS is to facilitate the safe and efficient movement of vessel traffic to prevent collisions, rammings, groundings, and the loss of lives, property and environmental quality associated with these accidents. Vessel Traffic Services, by

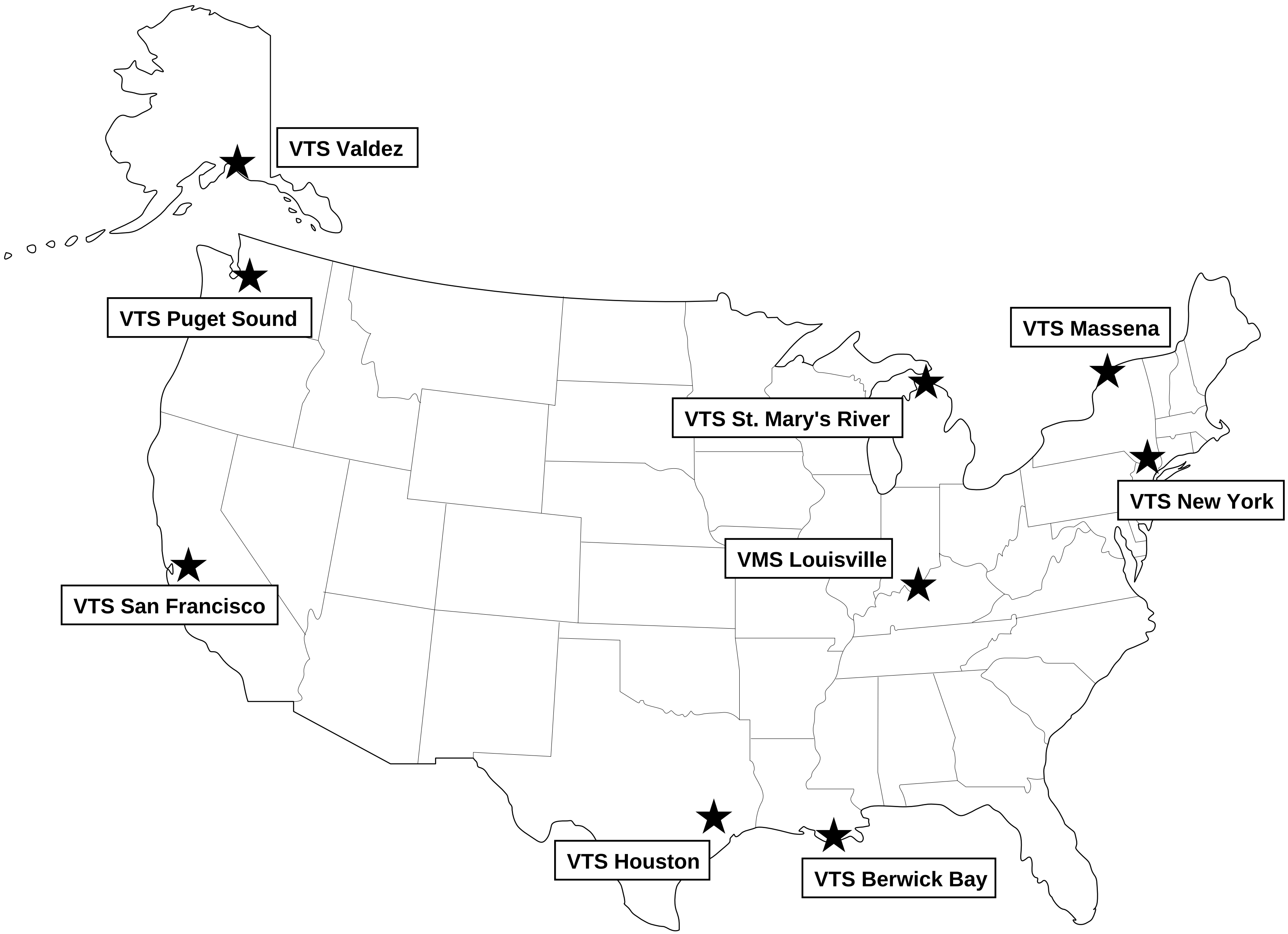


Figure 3-10. Vessel Traffic Service (VTS) Locations

their command and control facilities, also integrate and support other USCG missions including search and rescue, maritime law enforcement, anchorage administration, aids to navigation, port safety and security and national defense.

The SLSDC, created by Public Law 83-358 in 1954 (68 Stat. 93, 33 U.S.C. 981), is responsible for the development, operations and maintenance of the portion of the Saint Lawrence Seaway between Montreal, Quebec, and Lake Erie and within the territorial limits of the United States. In close coordination with the Canadian counterpart, the SLSDC maintains and operates a vessel traffic control center in Massena, New York (see Figure 3-10).

A. Operating Plan

Vessel traffic management can be either passive or active. Passive management involves compliance with the Rules of the Road and other rules and regulations. Active traffic management requires interaction and transfer of information between a shore station and a vessel. The USCG's objective in both passive and active vessel traffic management is to create a disciplined structure of order and predictability.

The USCG's authority, derived from the Ports and Waterways Safety Act (PWSA), allows for varying levels of vessel traffic management. The level of active management to be exercised is determined on a case by case basis and is directed at a specific vessel in a specific situation.

It is a generally accepted principle that VTS functions primarily as an advisory service to coordinate vessel movements through the collection, verification, organization, and dissemination of information. There are times, however, when the maintenance of good order on a waterway requires a VTS to be more directive in its dealings with a vessel. In the exercise of its authority, a VTS can be viewed as three-tiered relative to the level of direction it will exercise:

1. Informational/advisory - the most common use. The great majority of VTS operations are advisory or informative. The vessel operator receives information, determines if action is necessary, and makes adjustments in time to reduce the risks.

2. Recommendations - used occasionally. The VTS determines that action is necessary, and the vessel operator determines what specific action is required to comply, i.e., slow, change course, stop, etc.

3. Specific directions or orders - used in an emergency situation. The most common use of this authority is a VTS directing a vessel not underway to remain at berth or at anchor until an unsafe condition abates. In these cases, the VTS determines necessary and specific action to avoid a potentially dangerous situation.

"Positive Control," as distinguished from the above examples, is any order directed at a vessel by a VTS that affects the vessel's course or speed through the issuance of specific helm or engine commands. This level of involvement is inconsistent with the currently accepted practice within VTS, which is to manage the waterway through varying degrees of VTS interaction, and not by attempting to navigate a vessel from the shore. VTS maintains an informative and advisory role by providing mariners with as much information as is available to assist them in making sound judgements. VTS is active waterways management, not active vessel control. However, the PWSA provides the authority for the USCG to exercise positive control when deemed necessary. Although modern VTSs have the capability to exercise their authority to actively direct a vessel's movement, the USCG policy regarding VTS operations is that ultimate responsibility for safe navigation always remains with the master.

B. User Community

Mandatory participation by vessels is necessary for a successful VTS. Mandatory participation in the USCG's VTS program is generally aimed at vessels that are required to comply with the Bridge-To-Bridge Radiotelephone Act. In general terms, these are:

- Each vessel 20 meters or more in length.
- Each towing vessel 8 meters or more in length while towing.
- Each vessel of 100 or more gross tons carrying passengers for hire.
- Dredges and floating plants engaged in or near a channel or fairway.
- Vessels certificated to carry 50 or more passengers for hire, while engaged in trade.

Vessels that are specifically required to participate will be identified in VTS regulations and user's manuals.

In addition to participation requirements, vessel operators must be aware of the radiotelephone frequencies and assigned call signs for each VTS. Table 3-5 shows each VTS and its sectors, assigned frequencies, and voice call sign.

C. Acceptance and Use

VTS, as an international philosophy, continues to gain wide acceptance. Although VTS in some nations still tends to focus on economic issues, the trend is now toward safety of vessels, lives, and protection of the environment. Environmental issues are more in the forefront and initiatives are underway to ascertain how VTS can help protect the marine environment, while at the same time supporting a productive maritime economy.

As VTS becomes better known, and its international acceptance grows, the user community also grows. Table 3-6 shows the number of vessels that transited seven

Table 3-5. Vessel Traffic Services Designated[1] Radiotelephone Frequencies and Assigned Call Signs

VESSEL TRAFFIC SERVICES[2]	CARRIER FREQUENCY[3] (CHANNEL DESIGNATION)	CALL SIGN
NEW YORK	156.550 MHz (Ch.11) 156.600 MHz (Ch.12) 156.700 MHz (Ch.14)	NEW YORK TRAFFIC
LOUISVILLE	156.650 MHz (Ch.13)	LOUISVILLE TRAFFIC
HOUSTON	156.550 MHz (Ch.11) 156.600 MHz (Ch.12)	HOUSTON TRAFFIC
SARNIA		
MASSENA[4]	156.600 MHz (Ch.12) 156.650 MHz (Ch. 13)	SEAWAY EISENHOWER SEAWAY CLAYTON
BERWICK BAY	156.550 MHz (Ch.11)	BERWICK TRAFFIC
ST. MARY'S RIVER	156.600 MHz (Ch.12)	SOO CONTROL
SAN FRANCISCO	156.600 MHz (Ch.12) 156.700 MHz (Ch.14)	SAN FRANCISCO TRAFFIC
PUGET SOUND[5]		
Seattle Sector	156.250 MHz (Ch.5A) 156.700 MHz (Ch.14)	SEATTLE TRAFFIC
Tofino Sector	156.725 MHz (Ch.74)	TOFINO TRAFFIC
Vancouver Sector	156.550 MHz (Ch.11)	VANCOUVER TRAFFIC
PRINCE WILLIAM SOUND	156.650 MHz (Ch. 13)	VALDEZ TRAFFIC

Notes

1 The bridge-to-bridge navigational frequency, 156.65 MHz (Channel 13), is used in those vessel traffic service areas where the level of radiotelephone transmissions does not warrant the impact of requiring a designated vessel traffic service frequency. The U.S. USCG will continue to monitor vessel traffic service's use of this frequency and will petition the Federal Communications Commission for designated VTS frequencies if the need should arise.

2 Vessel traffic service geographical areas, sectors, and operating procedures are denoted in 33 CFR 161.

3 In the event of a communication failure on a designated frequency, either by the vessel traffic center or the vessel, communications may be established on an alternate VTS frequency, or 156.650 MHz (Channel 13); however, only to the extent that doing so provides a level of safety beyond that provided by other means.

4 The Canadian St. Lawrence Seaway Authority operates Seaway Beauharnois, Seaway Iroquois, and Seaway Welland for the Canadian sectors of the Seaway.

5 A Cooperative Vessel Traffic Service established by the United States and Canada within adjoining waters. The appropriate vessel traffic center administers the rules issued by both nations; however, it will enforce only its own set of rules within its jurisdiction.

of the eight USCG VTSs from January 1992 through December 1993. Statistics for the Vessel Traffic Management System in Louisville are not included in this list because this service is only temporarily activated during certain stages of high water.

D. Outlook

In August 1991, the USCG completed a VTS Port Needs Study to provide an economic framework for VTS capital investment decisions into the next century. This project examined 23 potential sites for VTSs and determined the benefit to be gained by establishing a VTS in terms of losses and damages avoided. The USCG is using the results of this study to establish new VTS systems nationwide.

Several initiatives are underway to upgrade and improve equipment at existing Vessel Traffic Centers. New surveillance techniques and equipment as well as enhanced displays are areas the USCG is emphasizing to improve service to the public.

In addition, the SLSDC has been investigating the use of GPS and DGPS in the St. Lawrence Seaway.

3.3 Interoperability of Radionavigation Systems

Radionavigation systems are sometimes used in combination with each other or with other systems. These combined systems are often implemented so that a major attribute of one system will supplement a weakness of another. For example, a system having high accuracy and a low fix rate might be combined with a system with a lower accuracy and higher fix rate. The combined system would demonstrate characteristics of a system with both high accuracy and a high fix rate.

3.3.1 Integrated Navigation Receivers

Integrated navigation receivers combine the signals from multiple sensors to determine position and, often, velocity. Typical sensors include one or more radionavigation receivers and, possibly, compasses and speed sensors. Commercial receivers which combine Transit and Omega or Transit and Loran-C have been widely produced. More recently, receivers have been developed combining GPS with other radionavigation systems to improve availability and coverage, increase integrity, and provide redundancy. Such receivers offer improved performance over the independent use of a single radionavigation system. These receivers fall under the category of augmented GPS.

The FAA has a project to determine the technical feasibility of using both GPS and GLONASS signals in the same user equipment to determine position and be used for navigation. In addition, the RTCA is developing a hybrid GPS/Loran-C MOPS. Integrity information from GPS and another system would provide better availability than when using either system separately - a benefit especially valuable in aviation.

Table 3-6. Vessel Traffic Services Currently Operating

FACILITIES	TOTAL VESSEL TRANSITS		
	1992	1993	1992+1993
NEW YORK, NY	177,789	162,893	340,682
PRINCE WILLIAM SOUND, AK	2,217	2,400	4,617
HOUSTON/GALVESTON, TX	176,277	179,912	356,189
PUGET SOUND, WA	258,666	272,392	531,058
SAN FRANCISCO, CA	90,289	87,419	177,708
BERWICK BAY, LA	88,739	103,897	192,636
ST. MARY'S RIVER, MI	49,769	33,750	83,519
TOTALS	843,746	842,663	1,686,409
AVERAGE			70,267/month

3.3.2 Interoperable Radionavigation Systems

Even better performance might be obtained by a user if the time references of different radionavigation systems were related to one another in a known manner. The systems would then be said to be interoperable, and user equipment could more advantageously combine the lines of position from the different systems.

Section 310 of Public Law 100-223, The Airport and Airway Safety and Capacity Expansion Act of 1987, caused an examination of the benefits of coordinating the time references of the GPS and Loran-C systems. While current national security considerations preclude the direct synchronization of Loran-C transmissions to GPS precise time, the USCG has significantly improved the synchronization of Loran-C master stations to UTC. Since GPS is also synchronized to UTC, this provides a de facto synchronization of Loran-C to GPS which might benefit the user.

The continuation of Loran-C overseas offers an opportunity to evaluate the potential of enhancing the use of Loran-C through Time of Transmission (TOT) control techniques. The new chains being planned for Northern Europe are being developed with this technique vice the USCG method of System Area Monitor (SAM) control. Once this system has been installed, and assuming the time base could be related to an independent radionavigation system, i.e., GPS, it is conceivable that appropriately developed user equipment could take advantage of Loran-C stations as ground based pseudolites. In addition to the common time base synchronization control technique, Europe is also considering the benefits of using the Loran-C signal as a method of disseminating GPS integrity messages and differential GPS. This could be accomplished through methods already used in the Loran-C system as it was developed to meet U.S. DOD requirements in the late 1960s and 1970s. In this system, referred to as Clarinet Pilgrim, the Loran-C signal was used as a carrier for passing data to submarines. Applying this concept to pass GPS integrity data and DGPS information might be possible. It remains to be seen if users, as well as commercial receiver manufacturers, will respond favorably to these enhancements.

3.4 Spectrum Certification of Radionavigation Systems

Radionavigation systems require certification of spectrum support prior to their implementation. A key requirement in the certification process is electromagnetic compatibility. Compatibility of systems is a shared responsibility of the DOD and DOT with further delegation of responsibility to the FAA, USCG and DOD frequency management authorities. To assist in meeting these responsibilities, the National Telecommunications and Information Administration (NTIA), in conjunction with the Interdepartment Radio Advisory Committee (IRAC), has developed procedures for the review of radionavigation systems and subsystems by the Spectrum Planning Subcommittee (IRAC/SPS) and for satellite systems review by the Space Systems Group (IRAC/SSG). Full participation of the FCC in these procedures, for operations in spectrum of mutual use by Government and non-government entities, occurs through the FCC liaison representation on the IRAC and its subcommittees. After coordination with the Deputy Associate Administrator, Office of Spectrum Management, the IRAC/SSG initiates the advance publication, international coordination and notification of Government space systems (including those in the radionavigation-satellite service) under the provisions of Articles 8,11,13 and 14 of the International Telecommunication Union (ITU) Radio Regulations and of Chapter 10 of the NTIA Manual. The IRAC/SSG is also responsible for reviewing and responding to the data furnished by other Administrations and the ITU regarding proposed space telecommunications systems in accordance with these ITU articles.